Fast Soft X-ray Beam Shutter

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Abstract. Most biological or polymer samples are radiation sensitive materials. A study of these materials at synchrotron radiation sources is challenging in order to minimize and systematically quantify exposure to the period of actual measurements. Since damage can occur on a scale of milliseconds there is a requirement for a beam shutter which can close and open in sub-millisecond times. At the Advanced Light Source two scanning transmission X-ray microscopes (STXM) have been equipped with innovative shutters.

INTRODUCTION

The successful commissioning of two scanning transmission x-ray microscopes (STXM) at the Advanced Light Source (ALS) has required the implementation of fast in-line x-ray beam shutters: One microscope is operating at a newly commissioned elliptically polarizing undulator (EPU) beamline (BL 11.0.2) while the other is operating at a novel dedicated bending magnet beamline (BL 5.3.2) [1,2].

The x-ray shutters are used to minimize sample exposure to x-rays in a controlled manner by exposing the sample only during precisely defined acquisition times. Experiments can then be designed and conducted to assess the rate of dosage and quantification of radiation damage to the sample material.

The monochromators deliver x-rays to a spot size of the order of 300 micrometers square after a final exit slit. This is then brought to a defined focus using achromatic Fresnel zone plates. The fine focus is used as a sensitive tool for micro-characterization of the sample but has the detrimental effect of concentrated exposure of x-rays on the sample. By judicious choice of defocused beam in comparison to exposure to focused beams a measure of the radiation damage and dosage brought about by "burning" or breaking of bonds in molecular structures can be quantified. This procedure has been developed by a number of groups and is indicative of the care that must be taken in quantifying and assessing any radiation damage [3,4].

The microscopes are used for the characterization of polymer and bio-materials via Near Edge X-ray Absorption Fine Structure (NEXAFS). Typically, line, point and image spectra are measured. Each mode of measurement requires a choice of dwell times and in particular no exposure of the sample during movement of the monochromator/EPU to requested photon energies. Additionally, during image scans the shutter is normally closed during 'fly-back' of the scanning stages.

The simple construction and implementation of the beam shutter would be of use to soft x-ray experimentalists not only on microscopy beamlines.

X-ray Beam Shutter

Figure 1 shows an isometric view of the shutter.

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CP705, *Synchrotron Radiation Instrumentation: Eighth International Conference,* edited by T. Warwick et al.

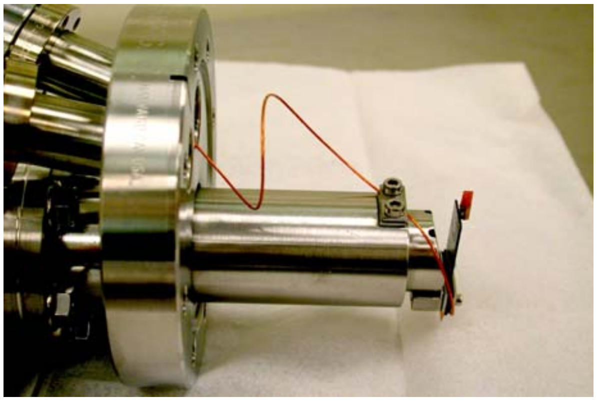

FIGURE 1. X-ray beam shutter. Shown are the piezo bender, copper shim and stainless steel stanchion.

The shutter is based on a single piezo bender [5] fastened between insulators and rigidly coupled to a linear manipulator via a stainless steel stanchion. A simple copper shim soldered perpendicular to the piezo completes the arrangement. The cooper shim is the actual beam-shutting element. The mass of the stainless steel attenuates any high frequencies coupling to/from the support structure and piezo actuation but is additionally rigid for precise placement in the beam. The beam size at the shutter position is about 200 μm, and the shutter motion is about 500 μm. The shutter is housed in a cube and isolated form the beamline and microscope using edge formed bellows. Since the STXM is extremely sensitive to any vibrations, special attention was given to this matter. No detrimental vibrations were observed from the shutter.

The shutter is controlled by a TTL pulse through a high voltage amplifier. The required working voltage to produce 500 μm displacement is 100V. To reduce the probability of a breakdown, the piezo bender is actuated using -50 V and +50V. During 3 years of operation there was not a single failure.

In soft X-ray spectroscopy, it is also of advantage to use filters like a suitable gas to minimize the effect of higher order contamination due to the monochromator and beamline. In our particular case, one of the shutters is installed in a differentially pumped gas filter arrangement, filled with ~3 mTorr of Nitrogen. In order to prevent discharge the piezo bender leaf was covered with a simple layer of PMMA after assembly.

Figure 2 shows the timing of the shutter response. There is an initial delay of about 300 μs, typical of piezo elements. The open/close time is about 500 μs. A characteristic of the piezo bender is a slow ringing oscillation upon activation by a square pulse. The result of this oscillation can be seen at about 3 ms after the initial pulse as a small dip in the resultant photon flux intensity.

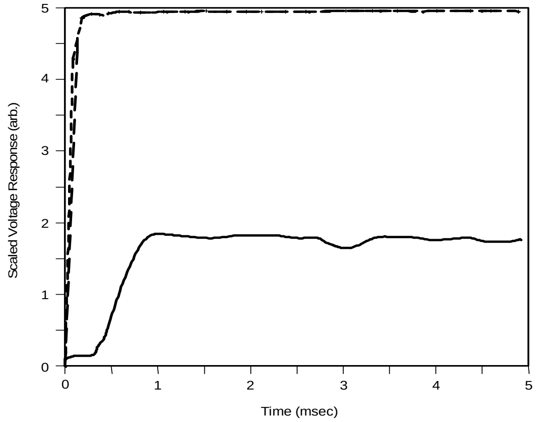

FIGURE 2. The piezo bender response under square wave pulsing. Short dashed line is an initial TTL pulse, the long dashed line represents the actuating voltage and the lower continuous line is x-ray flux measured with a photodiode.

To reduce this oscillation, a simple RC filter was used to modify the controlling TTL pulse. The value for the capacitor was found by experiment and a potentiometer used to fine tune the pulse in order to obtain a fast response without any oscillations. Figure 3 is an example of the response of the bender using the simple RC filter. The RC filter extends the initial delay to about 500 μs but does not change the close/open time. The response time of the shutter from the initial pulse to open/closed position is 1 ms, but since the initial delay is constant, an acquisition controlling program issues the signal appropriately earlier so the real time of shut/open is of the order of ~500 microseconds.

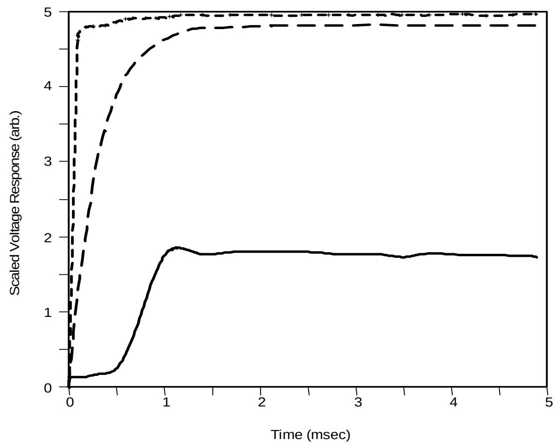

FIGURE 3. RC-filtered pulsing of the piezo bender. Short dashed line is an initial TTL pulse, the long dashed line represents the actuating voltage and the lower continuous line is the x-ray flux measured with a photodiode.

According to the manufacturer the bender can also be operated under resonance conditions, however, due to the variable dwell time requirements in STXM, this mode was not used. For faster response one can also shape the bender e.g., by cutting to a triangular shape but for our present use it was not necessary.

Conclusion

A simple but effective x-ray shutter has been presented that should find application in refining experiments that quantify and control radiation damage to materials.

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